

Reading Urban Ground Instability Through Traditional Water Infrastructure: Evidence from Historic Bhaktapur, Nepal

Rabin Rachalica^{1*}

¹Bhaktapur Tours Research Centre, Bhaktapur, Nepal

(*Corresponding E-mail: ssdetin@gmail.com)

Abstract: Urban ground instability in rapidly developing mountain valleys often becomes evident through cracking, settlement, waterlogging, drainage failure, and infrastructure damage. Historic Bhaktapur in the Kathmandu Valley offers an opportunity to examine these symptoms through its traditional water infrastructure. This study explores relationships among ponds, stone spouts (hitis), drainage routes, bridges, agricultural land, and settlements to understand changing ground and water conditions. Field observations followed Bhaktapur's 33 Ponds, 99 Hitis, and 33 Bridges circuits, alongside settlement expansion, agricultural-land conversion, surface drainage, waterlogging, and reported ground cracking. Traditional water infrastructure is considered both cultural heritage and a record of historical hydrological conditions and landscape adaptation. Preliminary interpretations suggest that disconnection of ponds, recharge areas, drainage paths, and water outlets may change local surface-water movement and increase vulnerability to waterlogging and localized ground instability. The study proposes a heritage-based engineering-geological approach that maps traditional water networks alongside current land use, drainage, settlements, and visible ground disturbances. This approach may offer low-cost indicators for locating areas requiring detailed geotechnical and hydrogeological investigation. These preliminary interpretations still require further detailed investigation. The findings emphasize integrating traditional environmental knowledge with modern hazard assessment to support resilient urban development in the Kathmandu Valley and other Himalayan settlements.

Keywords: Urban ground instability, Engineering geology, Traditional water infrastructure, Hiti, Ponds, Bhaktapur, Kathmandu valley, Hydrogeology, Urban resilience

Introduction

Many geological and hydrogeological processes operate gradually and remain unnoticed until they produce visible consequences. Ground settlement, changes in groundwater conditions, drainage obstruction, waterlogging, surface cracking and deterioration of infrastructure may develop through the interaction of natural processes and human modification of the urban landscape. These processes are particularly important in Himalayan valleys where rapidly increasing urbanization is occurring over complex geological, geomorphological and hydrological environments.

The central theme of INJSEG 2026, "Silent Forces of Nature and Growing Risks in the Himalayan Region," provides an appropriate framework for examining such gradual processes. Historic Bhaktapur offers an important case because its traditional urban system was developed in close relationship with ponds, stone spouts, drainage channels, agricultural land and settlement patterns. Many of these components remain visible even though their original hydrological functions have been reduced or modified.

This study therefore asks a practical engineering-geological question: can the surviving traditional water network provide useful evidence for identifying locations where changes in water movement, land use and settlement conditions may be associated with present-day ground instability?

Study Area

Bhaktapur is a historic urban settlement located in the Kathmandu Valley of Nepal, known for its traditional settlement structure and extensive network of water-related infrastructure. The urban landscape includes ponds, stone spouts (hitis), wells, drainage routes, courtyards, bridges, agricultural areas, and religious spaces, which have historically formed important components of the settlement. These features were not developed solely as individual structures but functioned as interconnected elements of the surrounding environment. Traditional water infrastructure served multiple purposes, including water supply, groundwater interaction, drainage, recharge, sanitation, and community management. The relationship between these structures and the surrounding settlement reflects how historical communities organized their urban environment while responding to local topographical and hydrological conditions.

The study focuses on three interconnected heritage-water circuits: the 33 Ponds Circuit, the 99 Hitis Circuit, and the 33 Bridges Circuit. These circuits provide a framework for examining the spatial relationships between traditional water bodies, drainage routes, transportation networks, agricultural land, and settlement areas. By studying these networks together, it becomes possible to better understand how different components of the traditional landscape were

connected and how they contributed to the movement and management of water within the settlement. The ponds and stone spouts represent important components of the historical water system, while the bridges and drainage routes provide additional references for understanding the relationship between water movement and the organization of the urban landscape.

Rather than considering these features only as individual heritage monuments, the study examines them as interconnected components of a broader urban environmental system. Their locations and relationships provide an opportunity to understand how traditional settlements responded to natural drainage patterns, local topography, and changing water conditions. The historical arrangement of ponds, stone spouts, drainage networks, and surrounding agricultural areas may also provide useful information about the interaction between surface water, groundwater, and settlement development. Examining these connections can help identify how traditional water infrastructure contributed to the functioning of the urban environment and how changes in the surrounding landscape may influence existing drainage and water movement.

Furthermore, the study highlights the importance of understanding traditional water infrastructure from both heritage and engineering-geological perspectives. The spatial distribution of ponds, hitis, bridges, and drainage routes provides a basis for examining the relationship between historical water management and present settlement conditions. By considering these networks collectively, the study establishes a framework for investigating how traditional environmental knowledge and historical landscape organization can contribute to understanding changing ground and water conditions in Bhaktapur. This approach emphasizes the value of preserving and examining traditional infrastructure not only for its cultural significance but also for its potential contribution to urban environmental assessment and future infrastructure planning.

Methodology

The study adopts a field-based interdisciplinary engineering-geological approach. Existing observations and field documentation from Bhaktapur Tours Research Centre were organized according to four principal spatial components: water infrastructure, drainage, land use and settlement conditions.

The 33 Ponds and 99 Hitis circuits were used to identify traditional water-storage and water-distribution locations. The 33 Bridges network was considered in relation to historical movement across drainage and low-lying areas. Field observations were then compared with present settlement expansion, agricultural-land conversion, altered drainage routes, waterlogging,

surface conditions and reported or visually observable ground cracking.

The methodology does not assume that every observed crack or drainage problem is caused by subsidence or geological processes. Instead, visible disturbances are treated as screening indicators requiring further engineering-geological, geotechnical or hydrogeological investigation.

A conceptual GIS-based framework is proposed in which historical water features, present land use, drainage networks, settlement density and ground-disturbance observations can be overlaid to identify areas of potential concern. This provides a practical pathway for converting heritage and community observations into preliminary engineering-geological information.

Results and Discussion

Initial field interpretation indicates that the traditional water system provides valuable spatial information about the historical relationship between water and settlement in Bhaktapur. Ponds and hitis were not randomly distributed; they formed part of an interconnected urban system associated with drainage, groundwater access, public spaces and settlement organization.

The reduction, alteration or disconnection of these elements may change the movement and storage of surface water. Conversion of agricultural land and open areas into buildings and paved surfaces can further modify infiltration and runoff pathways. Where traditional drainage routes are blocked, narrowed or replaced, rainfall runoff may accumulate in locations that historically performed different hydrological functions.

These changes are important from an engineering-geological perspective because water is a major factor influencing soil behavior, slope and ground conditions. In urban areas, localized water accumulation, leakage, altered recharge and changes in groundwater conditions may contribute to deterioration of foundations and infrastructure even when no major geological disaster is immediately visible.

An important observation from this study is therefore that traditional water infrastructure may serve as a historical baseline against which present urban environmental conditions can be compared. A disappeared pond, an abandoned hiti, a modified drainage channel or a buried water route may contain information about former hydrological conditions that is not apparent from the present urban surface.

The study consequently proposes the concept of “heritage-based engineering-geological screening.” Under this approach, traditional water features are mapped together with present ground disturbances and urban changes. Areas where multiple indicators overlap

can then be prioritized for detailed geotechnical investigation, groundwater monitoring, drainage assessment and infrastructure inspection.

Engineering-Geological Implications

The proposed approach has three principal implications.

First, traditional water infrastructure can contribute to preliminary hazard identification. Heritage maps and community knowledge can help identify former water-storage, drainage and recharge locations before expensive technical investigations are undertaken.

Second, the approach can strengthen urban resilience planning. Instead of treating heritage conservation and geological hazard management as separate activities, ponds, hitis and drainage networks can be considered components of urban environmental infrastructure.

Third, the method provides an opportunity for community-based monitoring. Residents, heritage groups, schools and local governments can document changes in cracks, waterlogging, drainage obstruction and infrastructure deterioration and contribute observations to a common engineering-geological database.

This approach is particularly relevant to Himalayan cities experiencing rapid urban expansion, where detailed subsurface data may be limited but historical landscape information remains available.

Conclusion

Historic Bhaktapur demonstrates that traditional water infrastructure can provide more than cultural and historical value. The spatial relationship among ponds, hitis, drainage routes, bridges, agricultural land and settlements preserves evidence of how an urban community historically adapted to local water and ground conditions.

The study proposes that these surviving networks be incorporated into preliminary engineering-geological assessment of urban ground instability. Mapping traditional water infrastructure together with present land-use change, drainage modification, waterlogging and visible ground disturbances can help identify locations requiring detailed geotechnical and hydrogeological investigation.

Rather than replacing conventional engineering-geological investigation, this approach provides a low-cost preliminary screening framework and a means of incorporating local knowledge and historical environmental information into modern hazard assessment. The Bhaktapur case demonstrates the potential for linking heritage conservation, hydrogeological understanding and urban disaster-risk reduction in the rapidly changing Himalayan region.

Acknowledgements

The author acknowledges the local residents, community members and participants involved in field observations and documentation of Bhaktapur's traditional water infrastructure.

Author Contributions

Rabin Rachalica conceptualized the study, developed the field-based research framework, conducted observations and prepared the manuscript.

Data Availability

Field observations and documentary materials used in this study are maintained by the researcher and Bhaktapur Tours Research Centre. Additional datasets can be developed through systematic GIS mapping and field verification.

Declarations

The author declares that there are no known competing financial interests or personal relationships that could have influenced the work reported in this study.

References

- Dahal, R. K. (2006). Engineering geological investigation and evaluation of landslide hazard in Nepal.
- Paudyal, K. R. (2014). Geological and structural characteristics of the Kathmandu Valley and surrounding region.